A SEMI-AUTOMATED WORKFLOW FOR PRODUCING TIME-ALIGNED INTERMEDIATE TONAL REPRESENTATIONS

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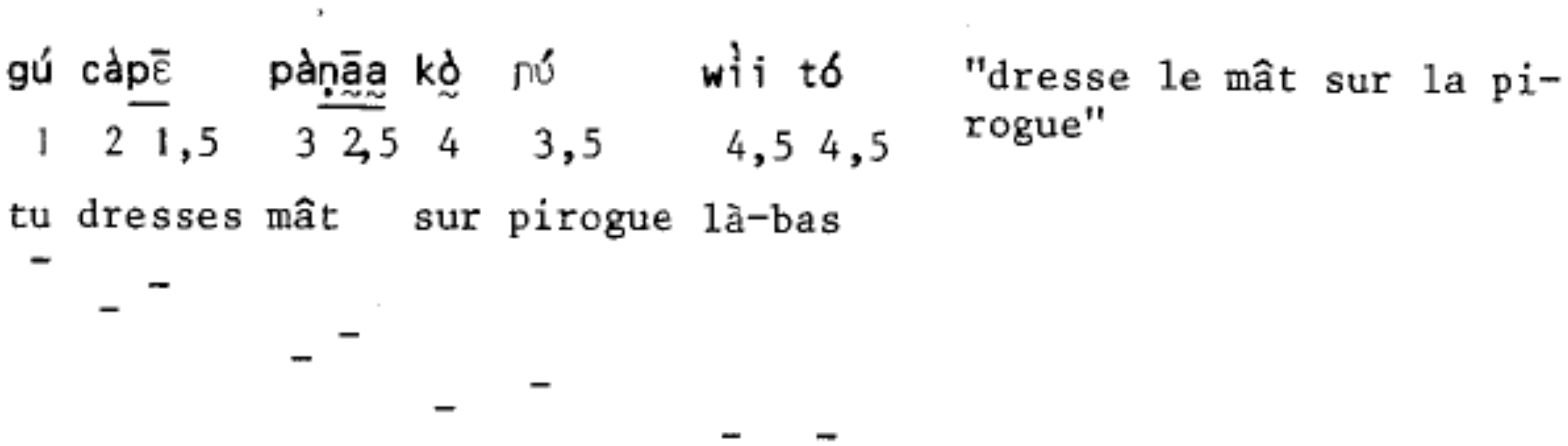
Introduction

The problem

- Tone is notoriously difficult
  - Inherently relative
- Early transcriptions unreliable
  - How many contrastive levels?
  - Are contours phonetic or phonological?
- Researchers are not always trained in tone
  - Community members
  - Linguists too

Annotations

- “Phonetic” annotations can be unsystematic and difficult to digitize:
  - [¯ –] [– _] [_ /] etc.



gú càpɛ̄ pàṇā̰a̰ kò̰ ɲú wìi tó "dresse le mât sur la pirogue"

1 2 1,5 3 2,5 4 3,5 4,5 4,5

tu dresses mât sur pirogue là-bas

Annotation of Numèè by Jean-Claude Rivierre (1973:134)

Annotations

- Phonological analyses often abstract, obscuring phonetic underpinnings

ɲḭ́ á mwḭ̀ḭ b̲ɛ̲́ɲḛ́ṛḛ́-ṛá "il est plus fort que moi"

il qui fort dépasser-moi

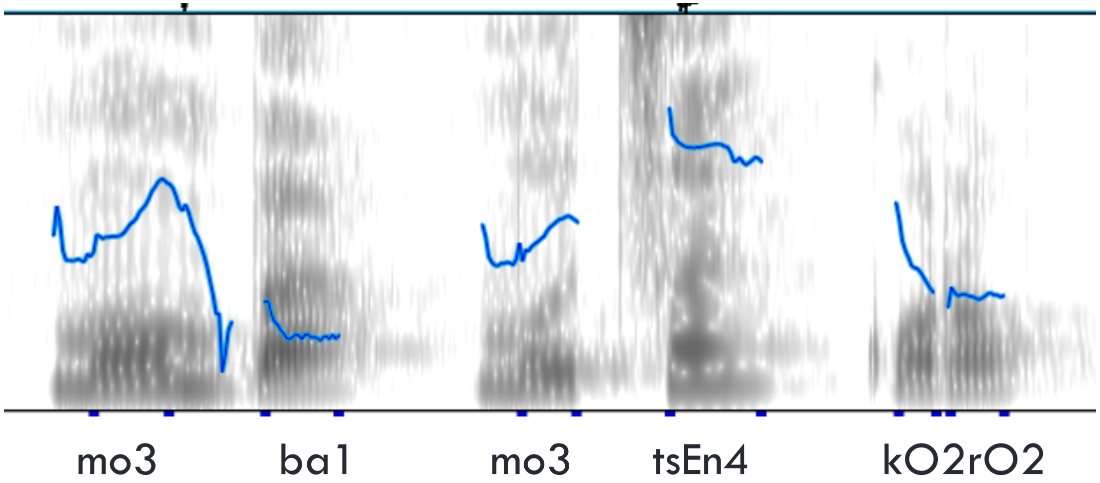
- No guarantee the researcher’s analysis is correct

The proposal

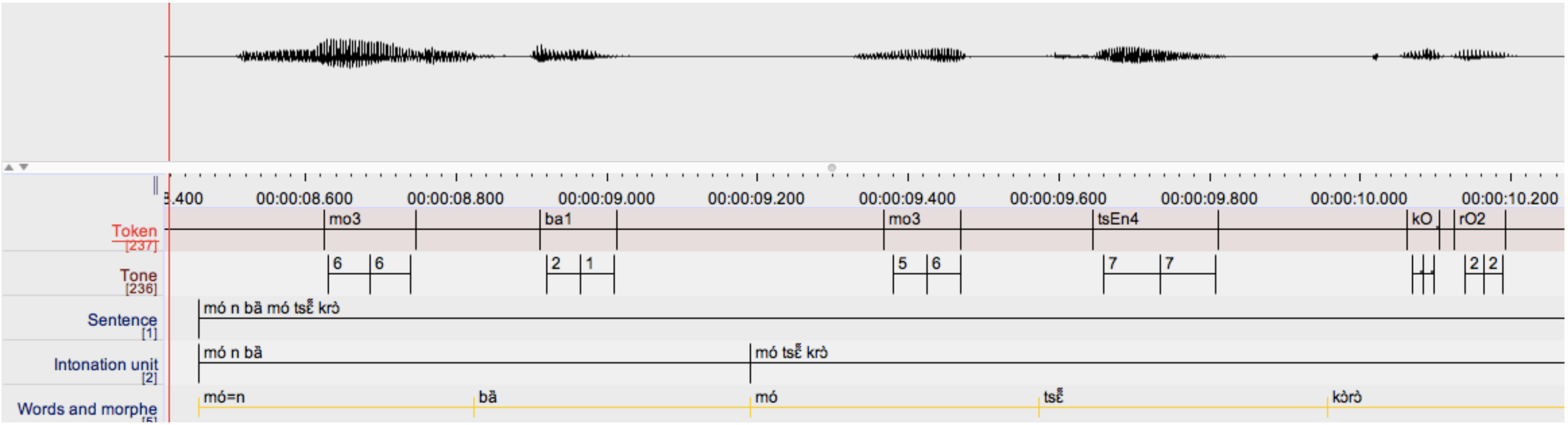
- We need a tool to help produce **objective, replicable** tone annotations from Day 1
- Desiderata:
  - Based on acoustic data (f0)
  - User friendly
  - Easily interpretable annotations
  - Interface with existing software and technology

The proposal

We want to go from this (f0, messy, hard to interpret):



To this (discrete levels, able to be digitized and included in annotations):



ATLAS

- ATLAS: Automated Tone Level Annotation System
- Annotates recordings for phonetic tone level based on normalized f0
  - Output is time-stamped
  - Can be imported into ELAN as a tonal tier
- NB: Does not replace the need for phonological analysis, but can appear alongside
- Analytical upshots:
  - Produces a searchable corpus of tone tied to other grammatical information
  - Annotations can be used to study phonetics or intonational realizations of tone

Today’s talk

□ Existing technologies for tone

□ Overview of ATLAS

□ Research applications

□ Conclusions/future work

Existing technologies for tone

Existing technologies

- Tone is relatively underserved technologically, but a few tools have been developed
- Focus on analysis of lexical/phonological tone, not surface/phonetic representation
- Two broad categories:
  - Hidden Markov models (language specific)
  - Clustering (language independent)

Hidden Markov Models

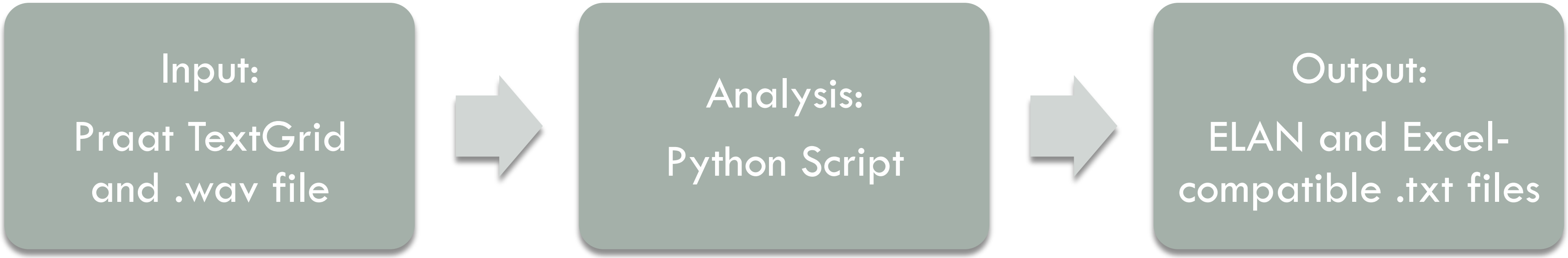
- Hidden Markov Models
  - Mandarin Chinese (Wu, Zahorian, and Hu 2013, Yang et al 1984)
  - Cantonese (Tan Lee et al. 1995)
  - Thai (Cooper-Leavitt 2016)
- Tone requires more context than most HMMs utilize (Bird 1994)
- Tools are limited to a handful of well-studied languages
  - All of which are East Asian contour-based tone systems

Clustering

- Not many computational tools for unstudied tone systems
- Toney (Bird and Lee, 2014)
  - Displays F0 contour on a canvas and allows the user to group similar contours together
  - Does not appear to be in active development

ATLAS: How it works

Three basic steps



Input:

Praat TextGrid and .wav file

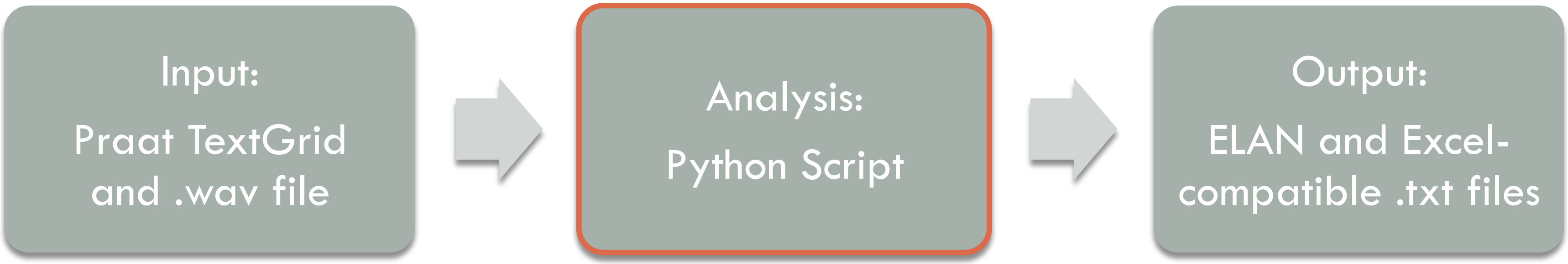
Analysis:

Python Script

Output:

ELAN and Excel-compatible .txt files

Three basic steps



Input:

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Python Script

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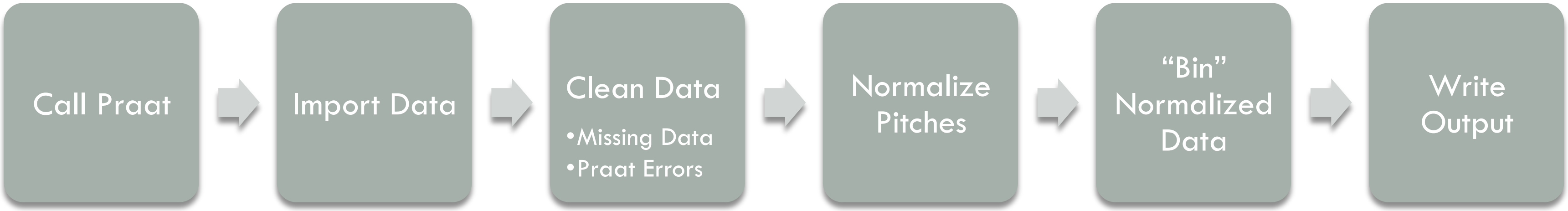
Python script: a closer look



Call Praat

Import Data

Clean Data

- Missing Data
- Praat Errors

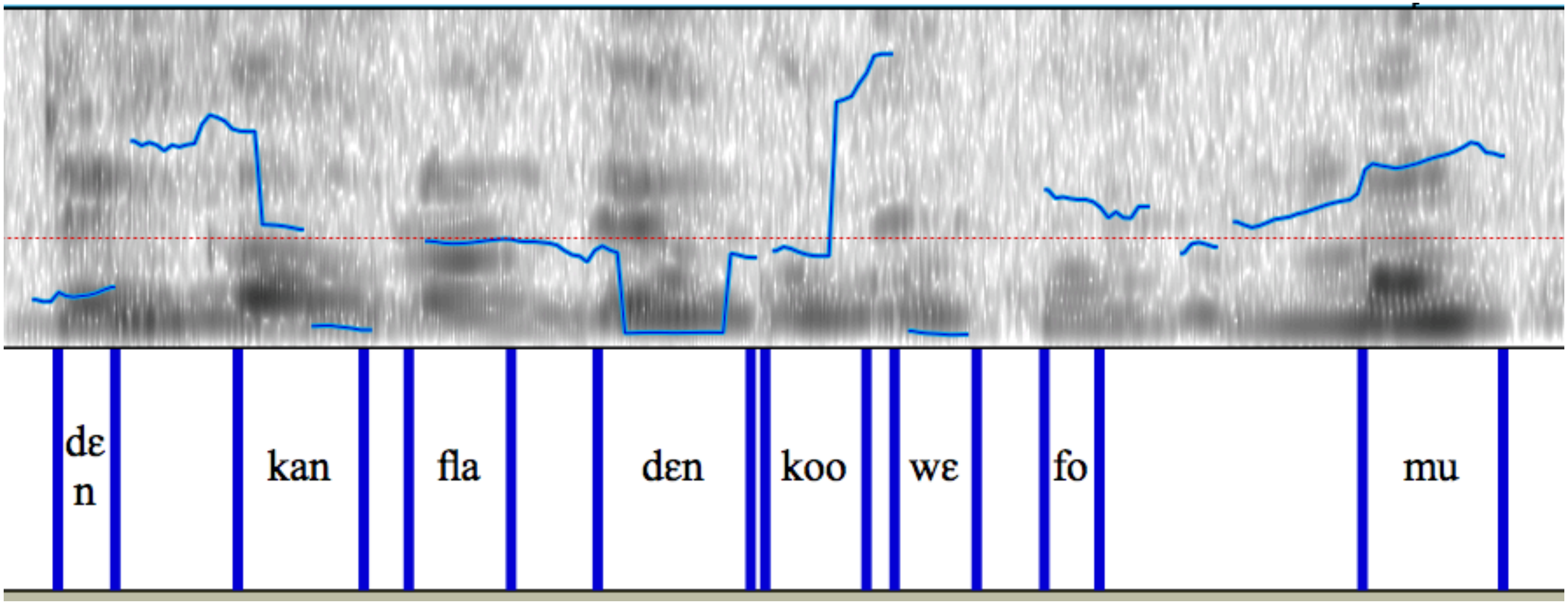
Normalize Pitches

“Bin” Normalized Data

Write Output

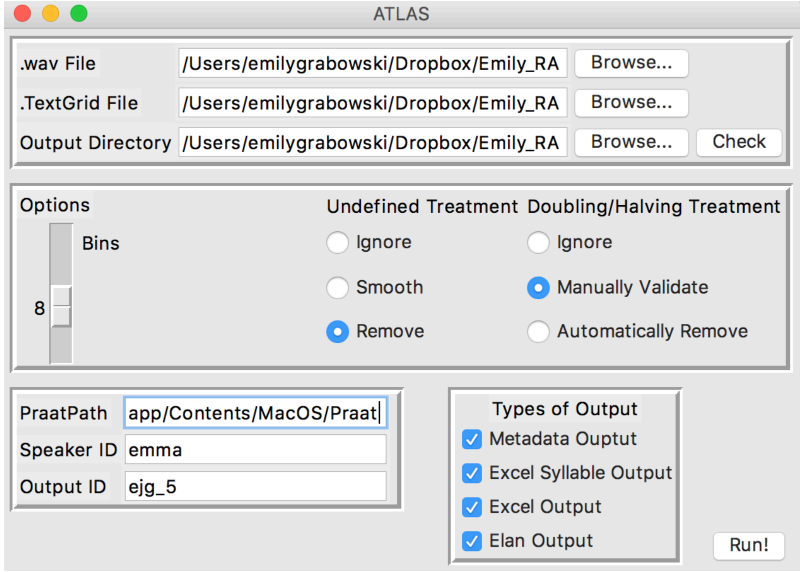
Input

- Semi-automated version requires a .wav file and Praat .TextGrid annotations as input
  - Annotate each TBU



Python script: a semi-automated tool

- Prompts the user to input arguments
- Currently command line tool
  - Initial arguments are input via a form
- Does not require the user to interface directly with Python



ATLAS

.wav File /Users/emilygrabowski/Dropbox/Emily_RA

.TextGrid File /Users/emilygrabowski/Dropbox/Emily_RA

Output Directory /Users/emilygrabowski/Dropbox/Emily_RA

Options

Bins 8

Undefined Treatment
○ Ignore
○ Smooth
● Remove

Doubling/Halving Treatment
○ Ignore
● Manually Validate
○ Automatically Remove

PraatPath app/Contents/MacOS/Praat

Speaker ID emma

Output ID ejg_5

Types of Output
☑ Metadata Ouptut
☑ Excel Syllable Output
☑ Excel Output
☑ Elan Output

Python Script: Cleaning the Data

Error	Cause(s)	How we deal with it
Undefined: Praat pitch-tracking not obtaining a signal	• Noisy/poor quality recording • TextGrid capturing part of a consonant	1. Remove all tokens with errors, or, 2. Smooth tokens with errors on boundaries, remove the rest
The Octave Problem (Doubling/Halving)	• Praat's algorithm thinks that the pitch is either an octave higher or lower • More often found with speakers with larger-than-average ranges	1. Automatically remove flagged tokens, or, 2. Manually confirm doubling/ halving
Outliers: Other	• Praat picked up data from outside the speaker • Speaker had one really high or low token	After correcting for the above two categories of errors, fit to a normal distribution (within 3 SDs) to find the speaker's probable range.

Python script: normalization

- Normalization allows for better comparison between speakers
- Hertz → semitones
  - cf. Baken 1987, Hart et al. 1990, Liberman and Pierrehumbert 1984, Ross et al. 1986, Xu 2004, etc.
  - A measure of frequency based on number of 'half-steps' (in the Western musical tradition) from a reference tone
  - Reference tone is the speaker's mean pitch in Hertz (after outlier correction)
  - Equation: $12(log_2(freq/ref))$

Python script: creating bins

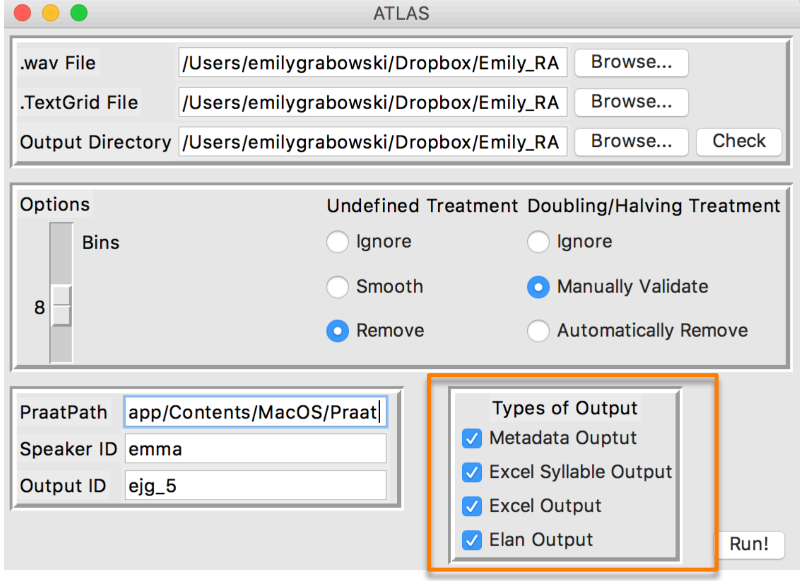
- Start with speaker's overall range (corrected for outliers)
- Range is divided up into equal parts (equal bins)
- User can specify the number of bins that they wish to use
  - More bins = more phonetic detail
  - We have found 8 to be a good number so far

Python script: assigning tokens to bins

- Take samples throughout the TBU
- Two extremes:
  - Could take as much as every 1/100th second throughout the TBU
    - Could be time-normalized for analysis
    - Can be overwhelming amount of detail
  - Could also do average for the overall token
    - Loses contour tone/phonetic detail
- Compromise: Measure at 20%/80%
  - Avoids consonant effects
  - Preserves contours and most important phonetic details

Output

- Desired output can be selected at the beginning:
- Main types
  1. ELAN-compatible (minimalist: time stamp + bins)
  2. Detail-rich spreadsheets
     - Two points (20%/80%) per syllable
     - Every 1/100s per syllable
  3. Metadata



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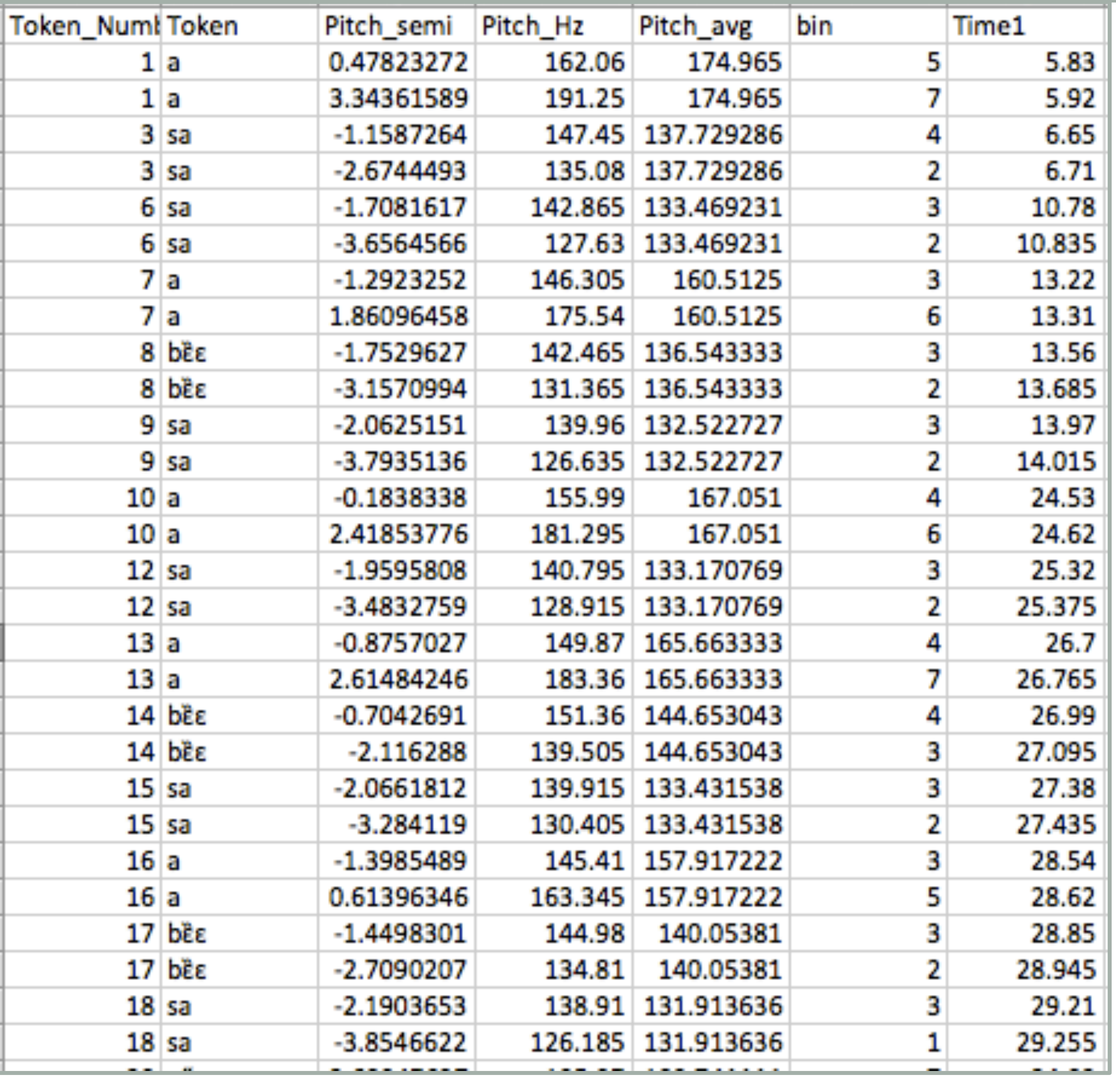
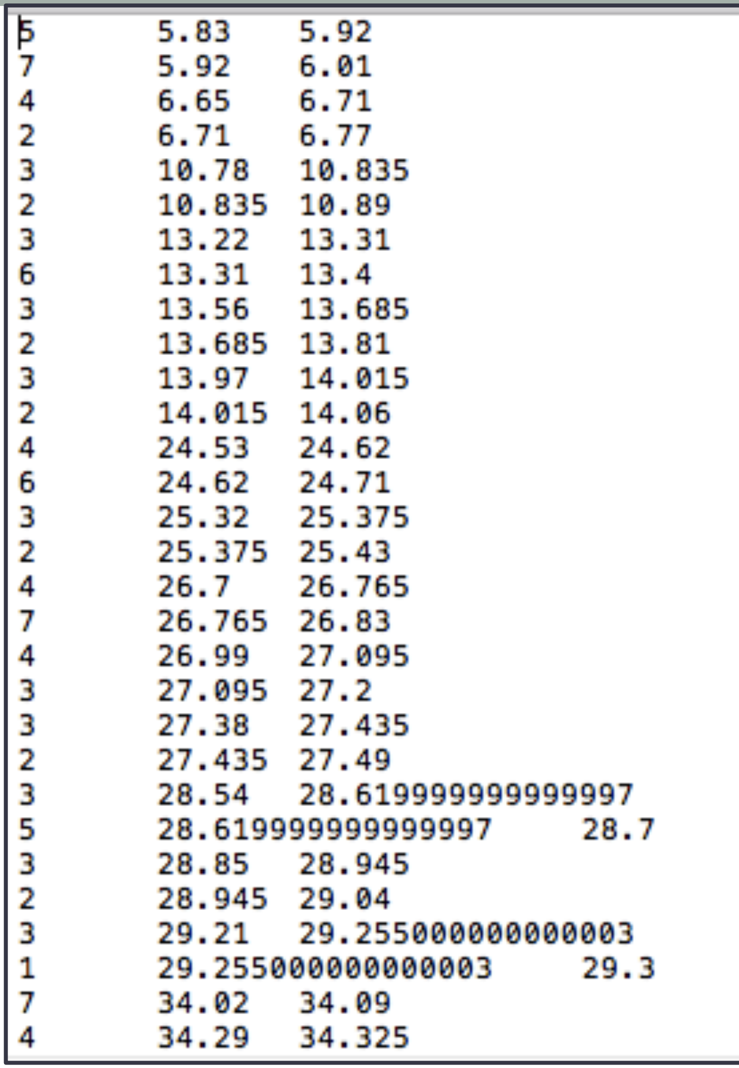
Output: .txt files

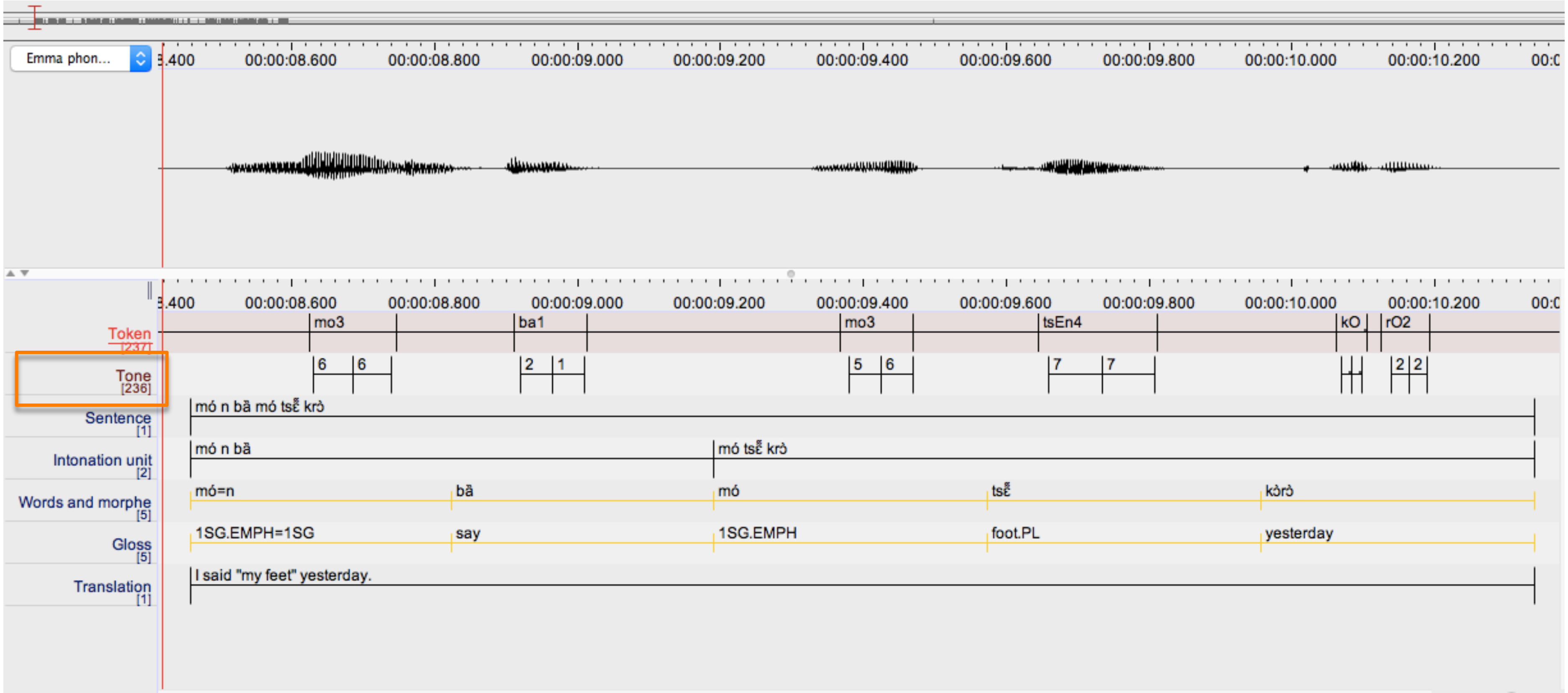


Token_Numl	Token	Pitch_semi	Pitch_Hz	Pitch_avg	bin	Time1
1	a	0.47823272	162.06	174.965	5	5.83
1	a	3.34361589	191.25	174.965	7	5.92
3	sa	-1.1587264	147.45	137.729286	4	6.65
3	sa	-2.6744493	135.08	137.729286	2	6.71
6	sa	-1.7081617	142.865	133.469231	3	10.78
6	sa	-3.6564566	127.63	133.469231	2	10.835
7	a	-1.2923252	146.305	160.5125	3	13.22
7	a	1.86096458	175.54	160.5125	6	13.31
8	bɛ̈ɛ	-1.7529627	142.465	136.543333	3	13.56
8	bɛ̈ɛ	-3.1570994	131.365	136.543333	2	13.685
9	sa	-2.0625151	139.96	132.522727	3	13.97
9	sa	-3.7935136	126.635	132.522727	2	14.015
10	a	-0.1838338	155.99	167.051	4	24.53
10	a	2.41853776	181.295	167.051	6	24.62
12	sa	-1.9595808	140.795	133.170769	3	25.32
12	sa	-3.4832759	128.915	133.170769	2	25.375
13	a	-0.8757027	149.87	165.663333	4	26.7
13	a	2.61484246	183.36	165.663333	7	26.765
14	bɛ̈ɛ	-0.7042691	151.36	144.653043	4	26.99
14	bɛ̈ɛ	-2.116288	139.505	144.653043	3	27.095
15	sa	-2.0661812	139.915	133.431538	3	27.38
15	sa	-3.284119	130.405	133.431538	2	27.435
16	a	-1.3985489	145.41	157.917222	3	28.54
16	a	0.61396346	163.345	157.917222	5	28.62
17	bɛ̈ɛ	-1.4498301	144.98	140.05381	3	28.85
17	bɛ̈ɛ	-2.7090207	134.81	140.05381	2	28.945
18	sa	-2.1903653	138.91	131.913636	3	29.21
18	sa	-3.8546622	126.185	131.913636	1	29.255



```
5       5.83    5.92
7       5.92    6.01
4       6.65    6.71
2       6.71    6.77
3       10.78   10.835
2       10.835  10.89
3       13.22   13.31
6       13.31   13.4
3       13.56   13.685
2       13.685  13.81
3       13.97   14.015
2       14.015  14.06
4       24.53   24.62
6       24.62   24.71
3       25.32   25.375
2       25.375  25.43
4       26.7    26.765
7       26.765  26.83
4       26.99   27.095
3       27.095  27.2
3       27.38   27.435
2       27.435  27.49
3       28.54   28.619999999999997
5       28.619999999999997      28.7
3       28.85   28.945
2       28.945  29.04
3       29.21   29.255000000000003
1       29.255000000000003      29.3
7       34.02   34.09
4       34.29   34.325
```

Output: tonal tier in ELAN



Token [237]: mo3 | ba1 | mo3 | tsEn4 | kO | rO2

Tone [236]: 6 | 6 | 2 | 1 | 5 | 6 | 7 | 7 | 2 | 2

Sentence [1]: mó n bă mó tsɛ̃ krò

Intonation unit [2]: mó n bă | mó tsɛ̃ krò

Words and morphe [5]: mó=n | bă | mó | tsɛ̃ | kòrò

Gloss [5]: 1SG.EMPH=1SG | say | 1SG.EMPH | foot.PL | yesterday

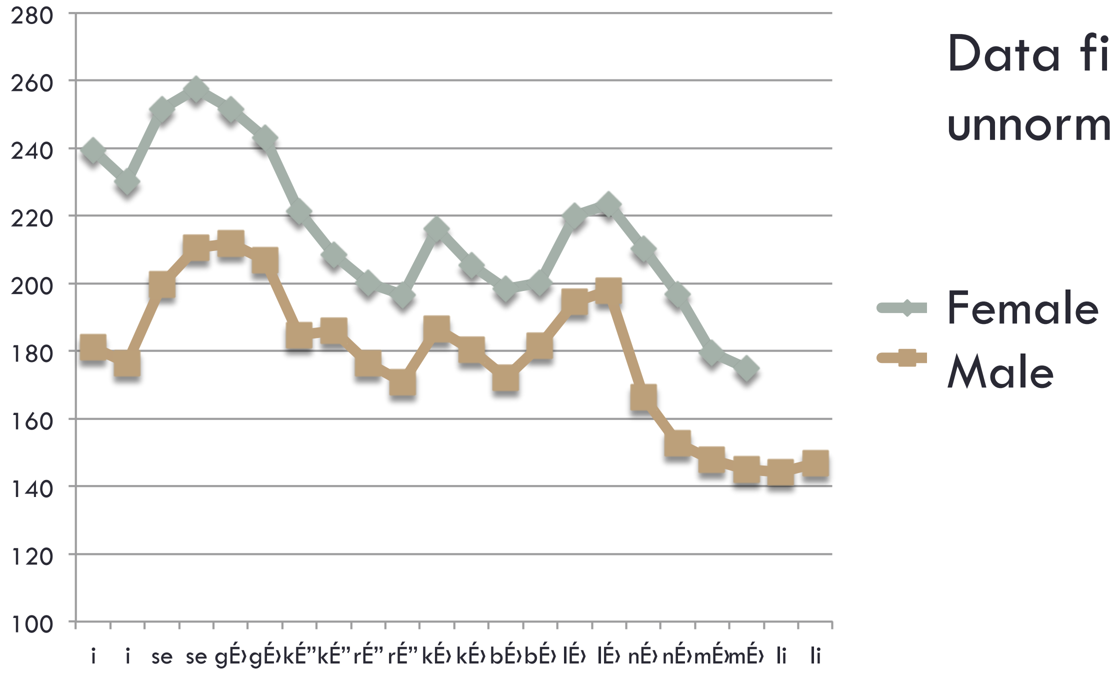
Translation [1]: I said "my feet" yesterday.

ATLAS: Research applications

Phonetic realization of tone

- With finer grain settings, phonetic realization can be visualized
- Case study: Tommo So (Dogon, Mali)
  - Two phonemic tones (H, L), plus surface underspecification (0)
- Controlled elicitation data from three speakers
  - 2 male, 1 female

Phonetic realization of tone



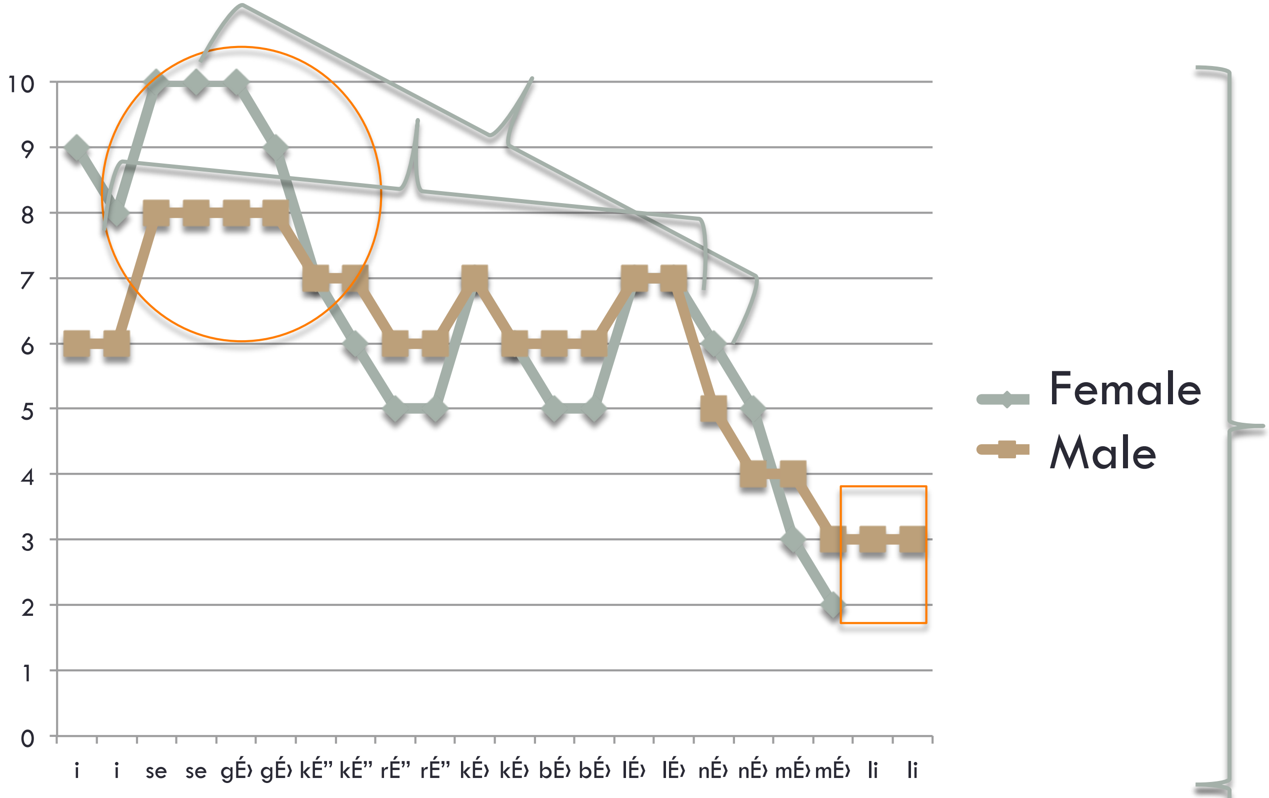
Data first in Hz (f0), unnormalized

L H 0 L L L L H L L H

ìsé = gɛ kɔ̀rɔ̀ kɛ̀bɛ̀lɛ́ nɛ̀mɛ̀-lí

‘the dog didn’t lick the calabash shard’

Phonetic realization of tone



ATLAS

L <u>H 0 L</u> L L L H L L H

ìsé = gɛ kɔ̀rɔ̀ kɛ̀bɛ̀lɛ́ nɛ̀mɛ̀-lí

‘the dog didn’t lick the calabash shard’

Human analysis

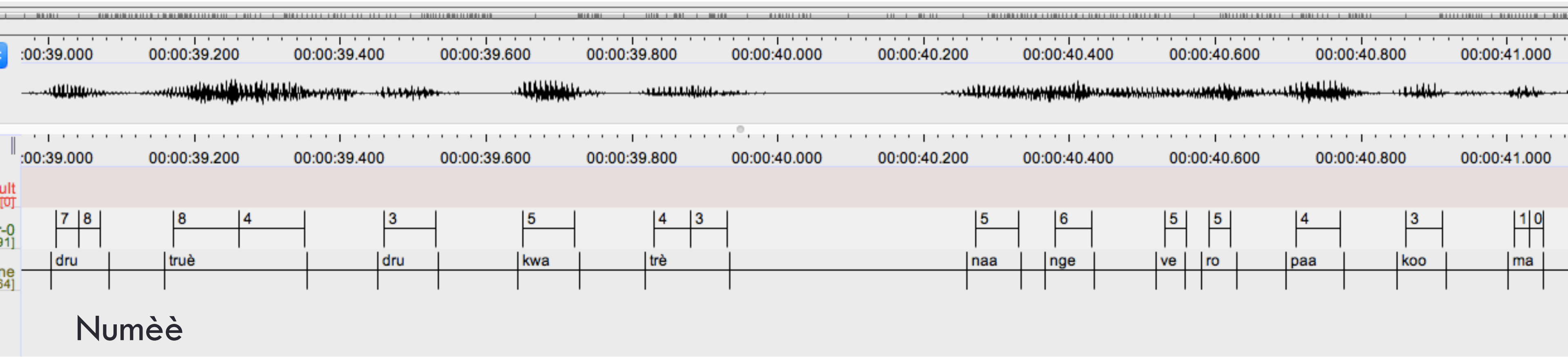
Confirming the literature

- Can be used in early stages of work to confirm descriptions in the literature
- Case study: Kwényï and Numèè (New Caledonia)
- Both languages are (probably) tonal, but neither tone system well understood
- Rivierre (1973) reports Numèè and Kwényï are mutually intelligible, but with opposite tone systems
  - Numèè overall falling melodies
  - Kwényï overall ascending ("plaintive") melodies

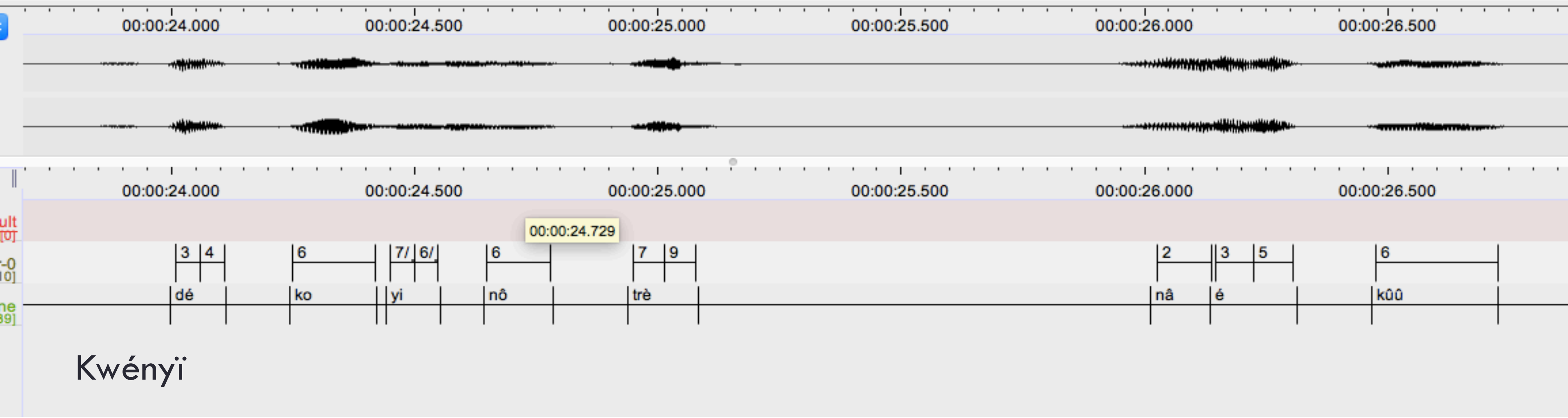
Confirming the literature

- Created TextGrids for a Kwényï narrative recorded in 2016 and a recording of Numèè from the LACITO archives
  - Both versions of a classic Melanesian “rat and the octopus” story
- Ran ATLAS with 10 bins

Confirming the literature



Numèè



Kwényï

Confirming the literature

- □ Average beginning and end levels for intonational units confirms the literature

	Average sentence beginning level	Average sentence ending level
Numèè	3.9	2
Kwényï	2.7	5.7

- □ Though Numèè typically rises before it falls
- □ Also an example of including tonal annotations for Kwényï before tonal analysis is complete

Conclusions

Summary of ATLAS

- Semi-automated tool to produce broad phonetic tone transcriptions
- User-friendly, requiring no programming knowledge and no prior experience with tone
- Transcriptions can be imported into ELAN

Summary of ATLAS

- ATLAS is **not** meant to:
  - Automate phonological analysis
  - Replace the need for phonological analysis and subsequent marking of tone
- Phonetic tonal annotations promote transparency and replicability
  - Whether alongside phonological analysis or on their own

Future development

- Fully automate, creating web and desktop versions
  - Forced alignment (e.g. FAVE, Rosenfelder et al. 2011)
  - Better interface with ELAN
- Optimization and development
  - Outliers
  - Doubling/halving
  - Maintaining speaker databases across recordings

To download the beta version…

- Go to dartmouth.edu/~mcpherson and follow the link on the home page.

Acknowledgments

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Data Organization

- Calls Praat script from Python (uses praatIO module developed by Tim Mahrt)
- Automatically imports the results
- TokenList:
  - Info (speaker id, etc.)
  - Token1
    - Info (e.g. # undefined tokens)
    - [Pitchentry1, Pitchentry2…]
  - Token2
    - Info
    - [Pitchentry1, Pitchentry2...]